ERDC/EL TN-10-2
May 2010

Evaluation of a Method for Measuring Lateral Obscuration of Coastal Marsh Vegetation in Louisiana

by Jeff P. Lin[1], Scott Bourne[1], Brady Couvillon[2], Jane M. Smith[1], Gregg Snedden[2], Gregory D. Steyer[2], and Sally L. Yost[1]

PURPOSE: This technical note presents the results of a pilot study evaluating the efficacy of using an image-derived, vegetative lateral obscuration ratio as an indicator of wave and flow hindrance in coastal Louisiana. The note discusses: (1) field methodology and equipment used to take the lateral photo, (2) comparisons between two different image analysis methods used to calculate the obscuration ratio, and (3) correlations among the obscuration ratios with vertical biomass distribution and density for two different coastal marsh plant species. Additionally, advantages, limitations, potential improvements to the methodology, and how results could be incorporated into wave attenuation modeling are also presented.

INTRODUCTION: Coastal marshes are known to significantly increase wave attenuation compared to unvegetated areas (Knutson et al. 1982; Koch et al. 2006; Möller 2006; Möller and Spencer 2002; Cooper 2005). Wave attenuation by vegetation is a function of both individual and community plant characteristics such as morphology (vegetation height, stem diameter, roughness, buoyancy, stiffness), plant spacing, landscape coverage, and seasonal variability; as well as hydrodynamic conditions such as water depth, wave height and period, wave orbital velocities, and turbulence intensity (Augustin et al. 2009; Cooper 2005; Möller et al. 1999). Studies of wave attenuation due to vegetation have been highly parametric and relate a friction or drag coefficient to a specific lab or field data set, limited by the vegetation type (or artificial surrogates, such as wooden rods), water level, and wave conditions. These results are difficult to apply to general conditions because of their empiricism over a very limited range of parameters (Knutson et al. 1982; Fonseca and Cahalan 1992; Lovas and Torum 2000; Wallace and Cox 2000; Cooper 2005). Generally, stem diameter and stem density are used to parameterize the dissipation, but these do not quantify the effects that varying plant species morphology have on waves, particularly through the range of emergent to submerged vegetation. This study is a preliminary attempt to better quantify aspects of salt marsh vegetation characteristics in coastal Louisiana that are relevant for wave attenuation modeling. Specifically, the study examines the feasibility of calculating an "obscuration ratio" (the percentage of a given vertical area that is obscured by a defined area of vegetation) as an indicator of species morphological differences, and relates this obscuration ratio to total plant above-ground biomass and density.

[1] U.S. Army Engineer Research and Development Center, Vicksburg, MS.
[2] U.S. Geological Survey (USGS) National Wetlands Research Center, Coastal Restoration Field Station, Baton Rouge, LA.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **MAY 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **2010Evaluation of a Method for Measuring Lateral Obscuration of Coastal Marsh Vegetation in Louisiana**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,,Vicksburg,MS**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**15**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Lateral obscuration ratios have been measured previously in *Spartina*-dominated coastal marshes in England by Neumeier (2005) and Moller (2006). However, no such studies have been conducted in Louisiana's coastal marshes. An important difference between the two regions is that the maximum *Spartina* height in the English marshes was generally < 30 cm, whereas the vegetation is much taller in coastal Louisiana marshes. The taller vegetation can create additional issues with regard to collecting lateral photos in the field; therefore, a modified version of the photographic method used in Möller (2006) has been developed to accommodate for the vegetation of coastal Louisiana. This study also serves as an assessment of this modified methodology, to determine how it could be improved for future use.

METHODS:

Field Methodology. Field samples were taken at 15 plots located in two separate areas of Biloxi Marsh (St. Bernard Parish) in Southeastern Louisiana (Figure 1). This marsh was selected because it was an important area for wave and surge propagation/attenuation during Hurricane Katrina in 2005. Wave and surge data were also collected in Biloxi Marsh during Hurricanes Gustav and Ike of 2008. In four of these plots the dominant vegetation was *Juncus romerianus* and at the other 11 plots the dominant vegetation was *Spartina alterniflora*. At each plot, photographs of vegetation were taken against a 50-cm-wide by 150-cm-tall plywood board that was painted using a high gloss, red paint. Wooden dowels extending from the side of the board were used to mark heights of 25 cm, 50 cm, 75 cm, and 100 cm on the board. Two sharpened metal pipes, affixed to the back that extended approximately 50 cm below the bottom of the board were used to plant the board into the marsh surface. Once the board was placed into the ground, a 50-cm by 50-cm PVC plot was laid down in front of the board. A tripod-mounted camera set at F35 focal length was placed 1.5 m away from the board. The height of the camera varied slightly among plots, from 65 to 72.5 cm. The camera focal length, distance, and height were adjusted so that the entire width and height of the board could be captured in a single photograph. To allow for an additional clearance area, any vegetation that did not have stems within the plot and that either stood between

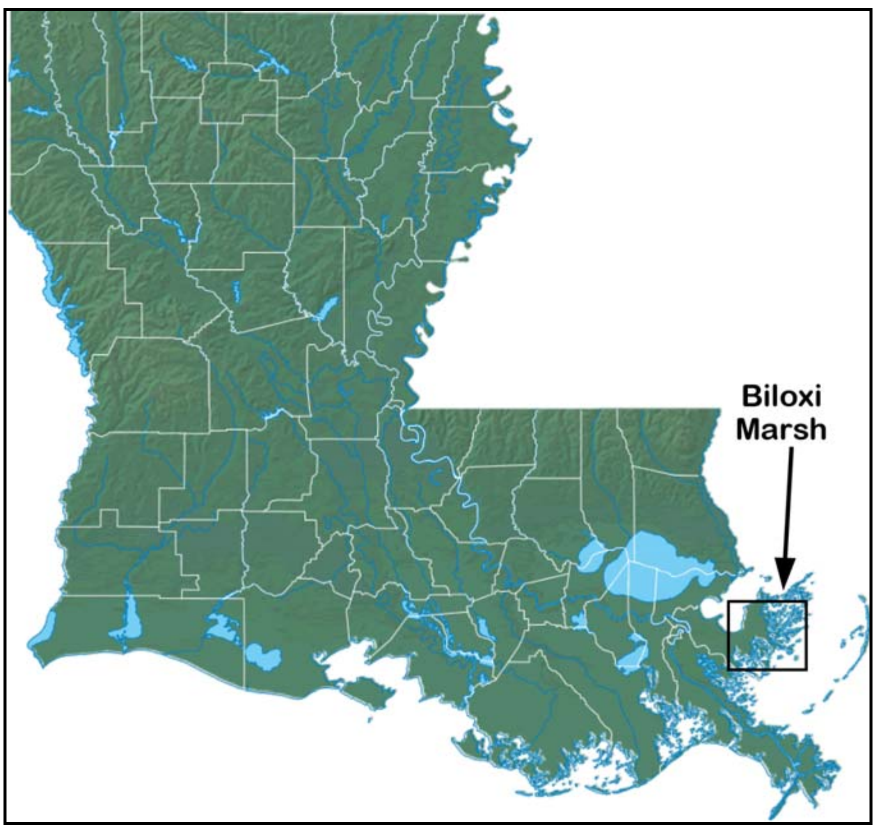

Figure 1. Location of Biloxi Marsh in Louisiana.

the camera and the board or was within approximately a meter to the sides of the board was pressed into the ground. For additional height reference, a meter stick was also placed vertically next to the board. Figure 2 shows an overview of this setup in the field. After photographs of the vegetation plot were taken, the first 20 cm of vegetation (30 cm away from the board) was harvested at the base, bound together, and placed in a large garbage bag for further analysis in the lab. Additional photographs were taken of the remaining 30 cm of vegetation. Following these photographs, the next 15 cm of vegetation was collected and then photographs were taken of the remaining 15 cm of vegetation in the plot, which was then also collected. Figure 3 shows examples of these photographs.

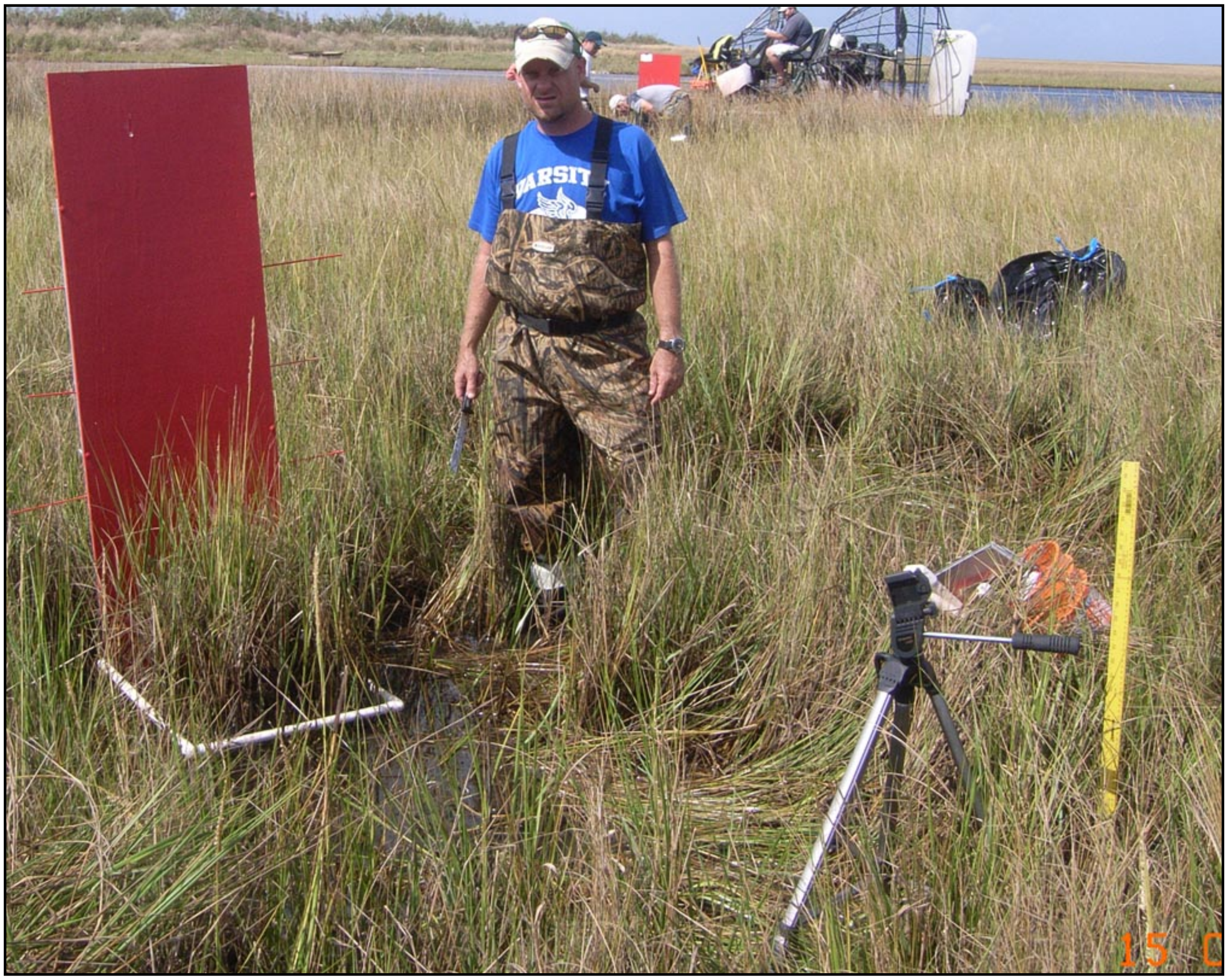

Figure 2. Setup used to take lateral obstruction photographs in the field.

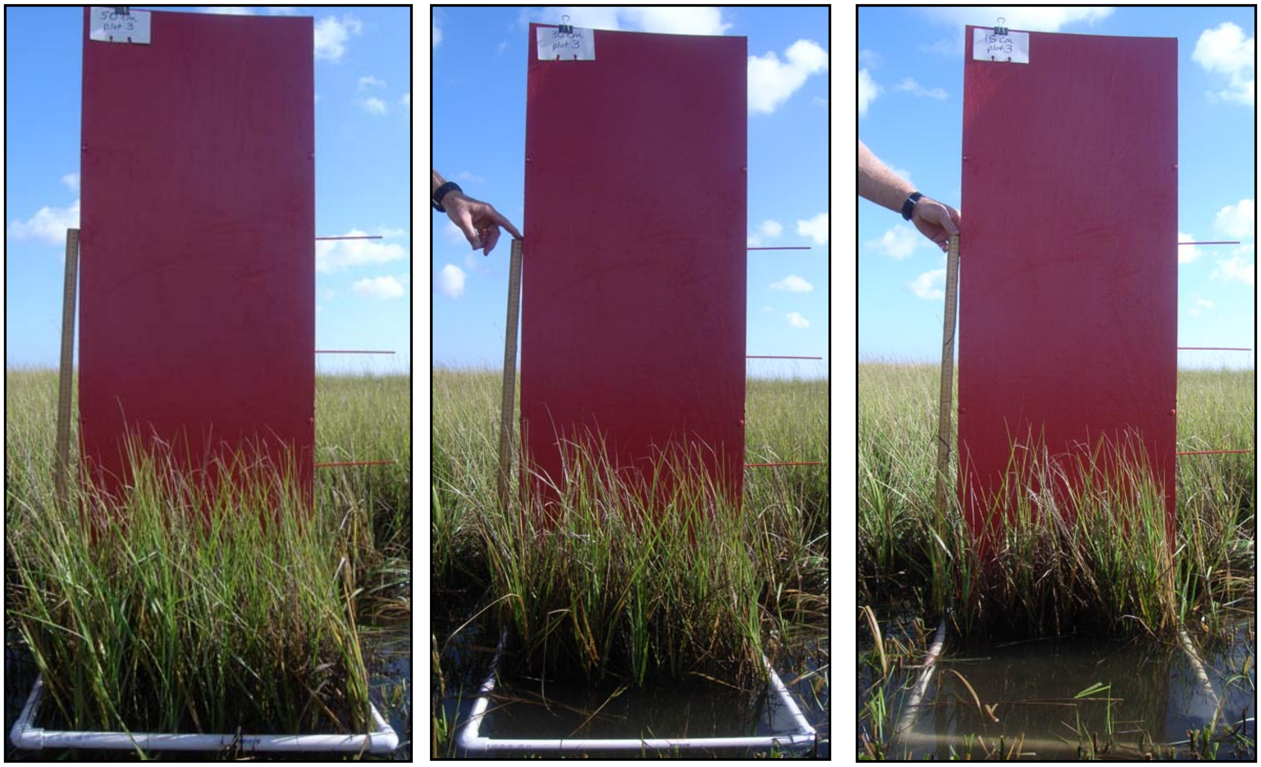

Figure 3. Lateral photos of 50-cm (left), 30-cm (center), and 15-cm (right) vegetation plots.

Laboratory Analysis. The bagged samples were taken back to the laboratory for further measurements. Stems in each bag were counted and identified, then aligned together at their bases and cut into 5-cm vertical increments. Each of these 5-cm samples was subsequently oven-dried at 80°C for 48 hr, then weighed to determine biomass by height.

Image Analysis. The extraction of plant features from photography has recently become a common practice. This plant extraction study is unique because the photography was not taken at a nadir position, but instead taken against a vertical red board with a hand-held digital camera. Both Feature Analyst (Visual Learning Systems, Inc. 2009) and an IMAGINE (ERDAS, Inc. 2009) ISODATA clustering algorithm were used to extract the plant features from the photos.

Feature Analyst is built as an extension to ArcGIS 9.3 (ESRI 2009) and utilizes a machine learning approach that is designed to automate feature extraction and incorporate software agent technology that learns to find features like hydrology, vegetation, and other features based on user-specified examples.

The first step in the analysis process was to clip out the portion of the image that the red board occupied so that image processing would only be performed in the area of interest (AOI). After the AOI was clipped, the training set was created. The training set consists of examples that demonstrate the variety of spectral signatures of the feature class, which are used to train Feature Analyst Learner. Learner uses an algorithm to determine the numerical signatures for the training class. Learner then compares each pixel in the image to the signatures and determines which pixels most closely resemble the pixels in the training class. Having a variety of spectral signatures is important, but the orientation, size, and shapes of the classes are also crucial. It is also essential to select features across the extent of the image to reduce the potential effects of shadows. The importance of generating a good training set cannot be over-emphasized. If the training set is poorly digitized and not representative of the target features, there will be no combination of learning parameters that will provide good results. Figure 4 shows the training classes that were generated for one of the images.

Figure 4. Example of training classes used to train the Feature Analyst Learner.

Once the training set was defined, the next step was to set up the learning parameters. The feature selector Graphical User Interface (GUI) provides pre-defined extraction options designed to generate the quickest feature extraction based on the basic characteristics of the features to be delineated. For this analysis, the Narrow Linear Feature (<10 m) and Bull's Eye 1 input representation were used. The Bull's Eye pattern is appropriate for small features of less than 5 m, and for narrow linear features less than 10 m. After testing many of the input representation choices, it was determined that the Bull's Eye provided the best results.

Once the Learning parameters were set, the initial extraction process was completed for the photo. The first iteration excluded many vegetation features, requiring many more iterative processes to achieve satisfactory results. To begin clutter removal and to further refine the classification process, a series of correct and incorrect examples were identified. Missed features were also identified during this phase of the process. This enables feature analyst to learn from any mistakes that may have been made during the initial classification. Only two or three iterations of this process were needed to produce the desired results. Because of the glare on the board and shadows created by the vegetation, some manual editing had to be implemented to address additional areas of clutter that were not removed during the automated process. Figure 5 shows an example of the final results of the feature extraction.

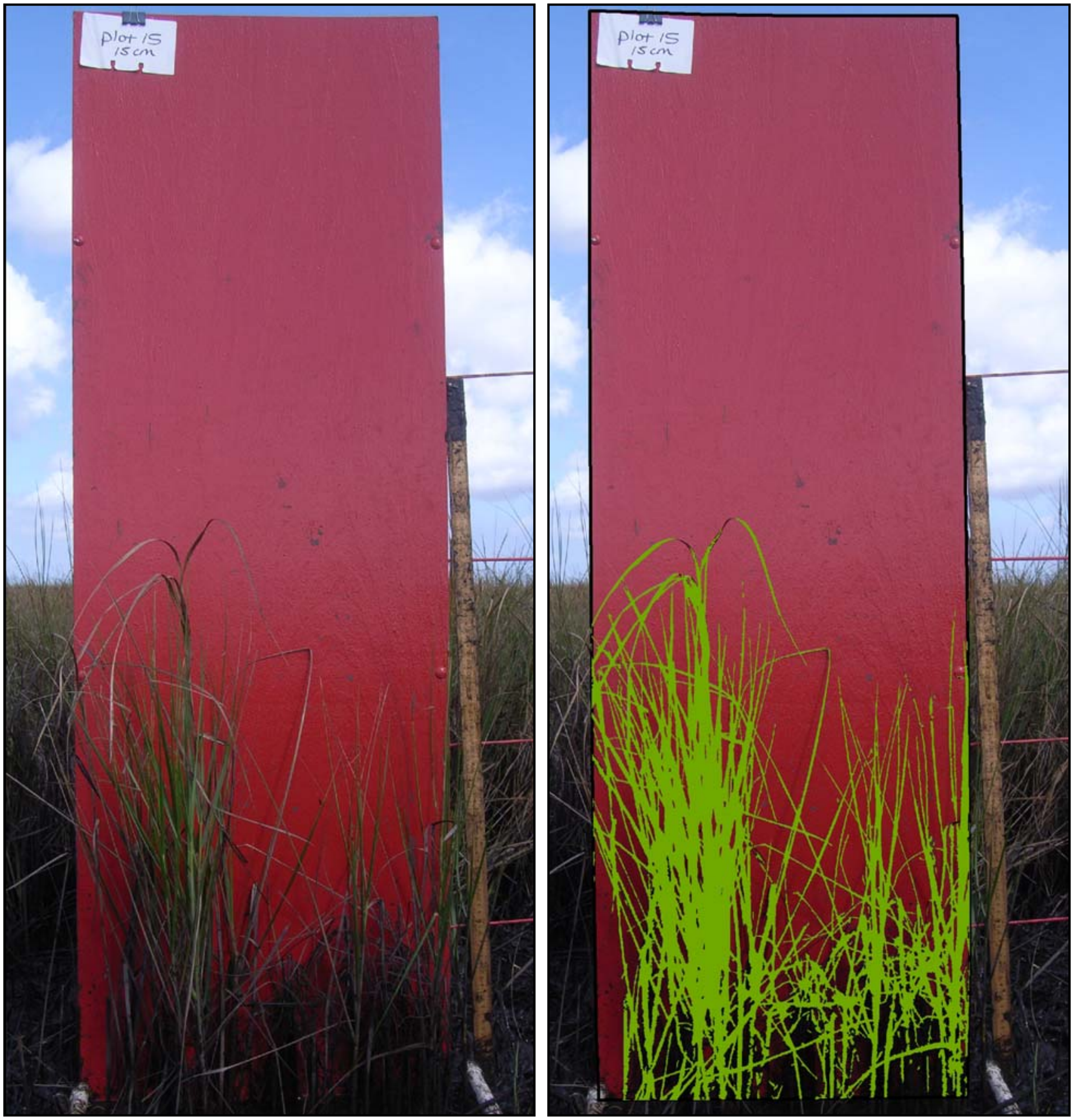

Figure 5. Original photo (left) and resulting vegetation extraction image (right) created using Feature Analyst.

Once vegetation was extracted from the image, obscuration percentage was calculated for 0- to 50-cm, 50- to 100-cm, and 100- to 150-cm height increments of the board.

The ERDAS ISODATA extraction method differed from the Feature Analyst method in that it did not utilize a training data set. Additionally, classification using ERDAS ISODATA was based purely on three-band spectral characteristics, without consideration to the orientation, size, and shapes of the classes. The following input parameters were used for the classification:

- Output cluster layer
- Output signature set
- Approximate true color
- Maximum iterations: 20
- Convergence threshold: 0.975
- Skip factors 1:1
- 40 classes

Signature sets were examined visually and statistically to determine which classes would be recoded to board, vegetation, and shadow. Questionable signatures were alarmed and the interpreter made a subjective decision to determine which class was most appropriate for that signature. Next, a recode was conducted to create a thematic four-class image (board, vegetation, shadow, sky). Finally, the percentage of board, vegetation, and shadow were calculated for each height increment.

In some photos, a portion of the vegetation was under water. In these cases, for both analysis methods, the obscuration percentage of any underwater vegetation was assumed to be identical to any vegetation that was above water within the 0- to 50-cm height increment.

RESULTS:

Comparison of Above-Ground Biomass and Image Obscuration. Table 1 displays results for *S. alterniflora*-dominated plots with the mean biomass and obscuration data by depth and height increment, as well as total plant stem density for each depth. Table 2 displays the same information for the *J. romerianus*-dominated plots. Two sample T-tests were performed to compare biomass, obscuration percentage, and density for each depth between the two types of vegetation plots. No significant differences ($p > 0.05$) were found in biomass or obscuration percentage for the 0- to 50-cm height increment at any of the three depths. Significant differences ($p < 0.05$) in biomass and obscuration percentage occurred in both the 50- to 100-cm and 100- to 150-cm height increments at all three depths. Additionally, there were significant differences in stem density between the two vegetation types at all three depths.

Table 1. Mean and Standard Deviation (SD) for Biomass, Obscuration Percent, and Density at Various Depths and Height Increments for *S.alterniflora* Dominated Plots. N = 11.

Vegetation Depth (cm)	*S. alterniflora* Vegetation Height Increment (cm)						Density/SD (stems/m^2)
	0–50		50–100		100–150		
	Biomass/SD (g)	Obscuration/SD (%)	Biomass/SD (g)	Obscuration/SD (%)	Biomass/SD (g)	Obscuration/SD (%)	
15	72.44/17.19	49.43/10.05	8.64/14.72	8.64/6.15	0.97/2.97	0.89/2.67	811/332
30	130.38/25.76	64.98/11.47	15.81/25.47	14.95/14.14	1.70/5.11	1.48/4.28	738/302
50	201.49/24.69	66.81/10.64	23.66/34.19	21.99/17.38	2.39/6.79	1.95/5.13	708/226

Table 2. Mean and Standard Deviation (SD) for Biomass, Obscuration Percent, and Density at Various Depths and Height Increments for *J.romerianus* Dominated Plots. N = 4.

Vegetation Depth (cm)	*J. romerianus* Vegetation Height Increment (cm)						Density/SD (stems/m^2)
	0–50		50–100		100–150		
	Biomass/SD (g)	Obscuration/SD (%)	Biomass/SD (g)	Biomass/SD (g)	Obscuration/SD (%)	Biomass/SD (g)	
15	87.86/10.55	55.56/7.50	41.85/11.69	27.51/7.72	4.56/0.68	5.04/3.66	1,333/443
30	160.80/41.20	68.17/7.04	71.99/28.62	42.98/11.41	6.99/2.26	9.20/9.69	1,185/455
50	253.69/35.99	77.56/10.22	111.05/14.42	59.90/10.98	11.41/4.15	14.46/7.51	1,122/299

Separate non-linear regression analyses were performed on image obscuration versus biomass vegetation for plots dominated by *S. alterniflora* (Figure 6) and *J. romerianus* (Figure 7), and a positive relationship was found for both species. For the purposes of the analysis, data from the different depth increments (15 cm, 30 cm, and 50 cm) were combined.

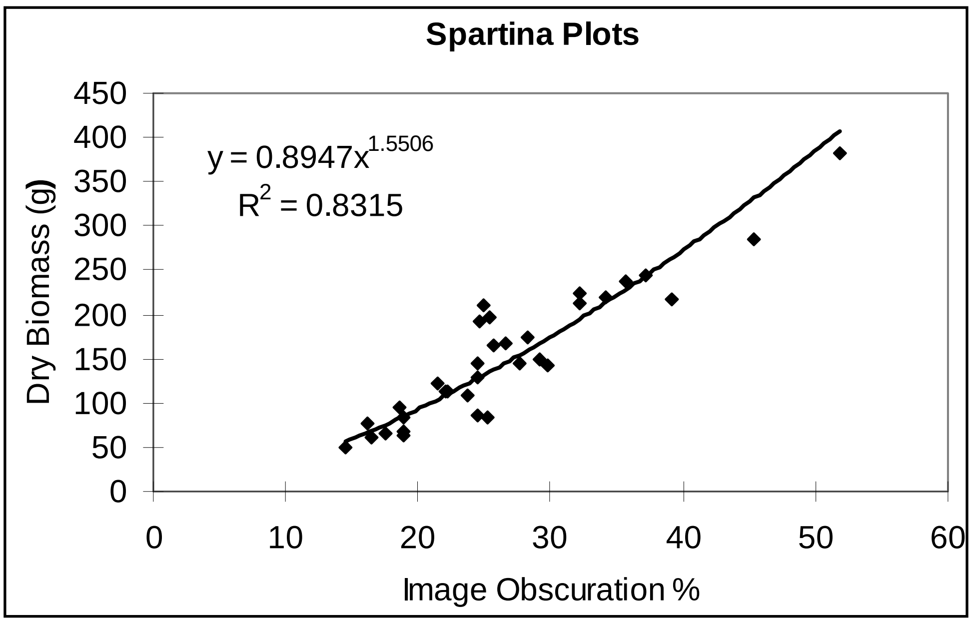

Figure 6. Non-linear regression of image obscuration versus biomass in *S.alterniflora*-dominated plots.

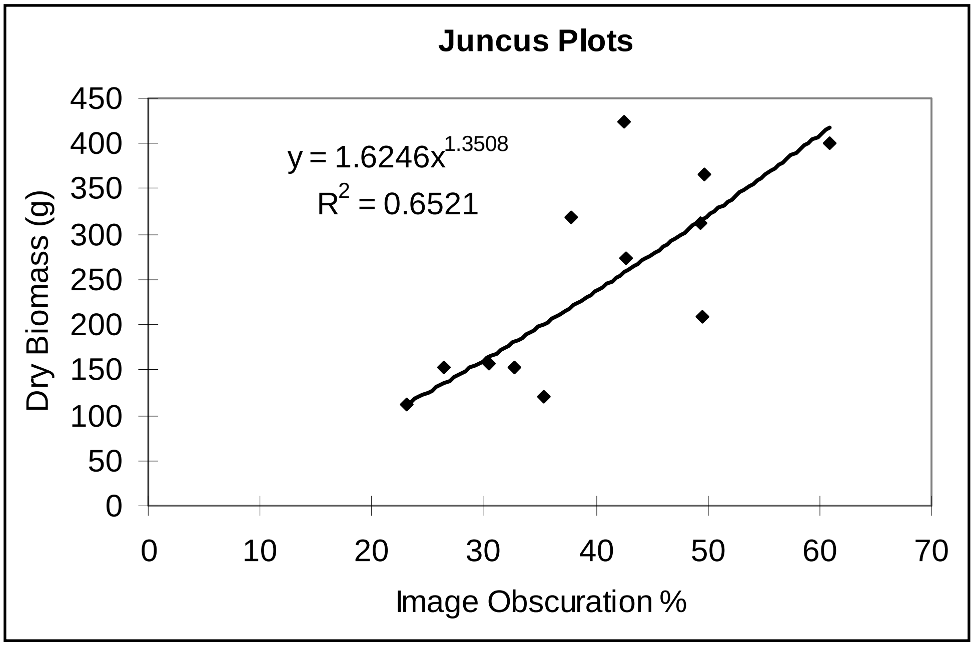

Figure 7. Non-linear regression of image obscuration versus above-ground dry biomass in *J. romerianus*-dominated plots.

Regression analyses were also performed on image obscuration versus stem density for both vegetation types of plots (Figure 8). High variability in stem densities contributed to a weak relationship with image obscuration. The stem count includes all species that were found in a plot. On average, *S. alterniflora* plots contained about 84 percent *S. alterniflora* based on stem density (other species found in these plots were *Spartina patens*, *Schoenoplectus robustus*, and *Distichlis spicata*), while *J. romerianus* plots contained about 90 percent *J. romerianus* based on stem density (other species found in these plots were *S. alterniflora* and *D. spicata*).

Image obscuration ratios calculated for three photos using both the Feature Analyst and IMAGINE ISODATA software techniques are compared in Table 3. There was no consistent pattern to the differences in obscuration ratio measured using the two techniques, which suggests that the differences are based more on the individual conducting the analysis, rather than the technique or software used.

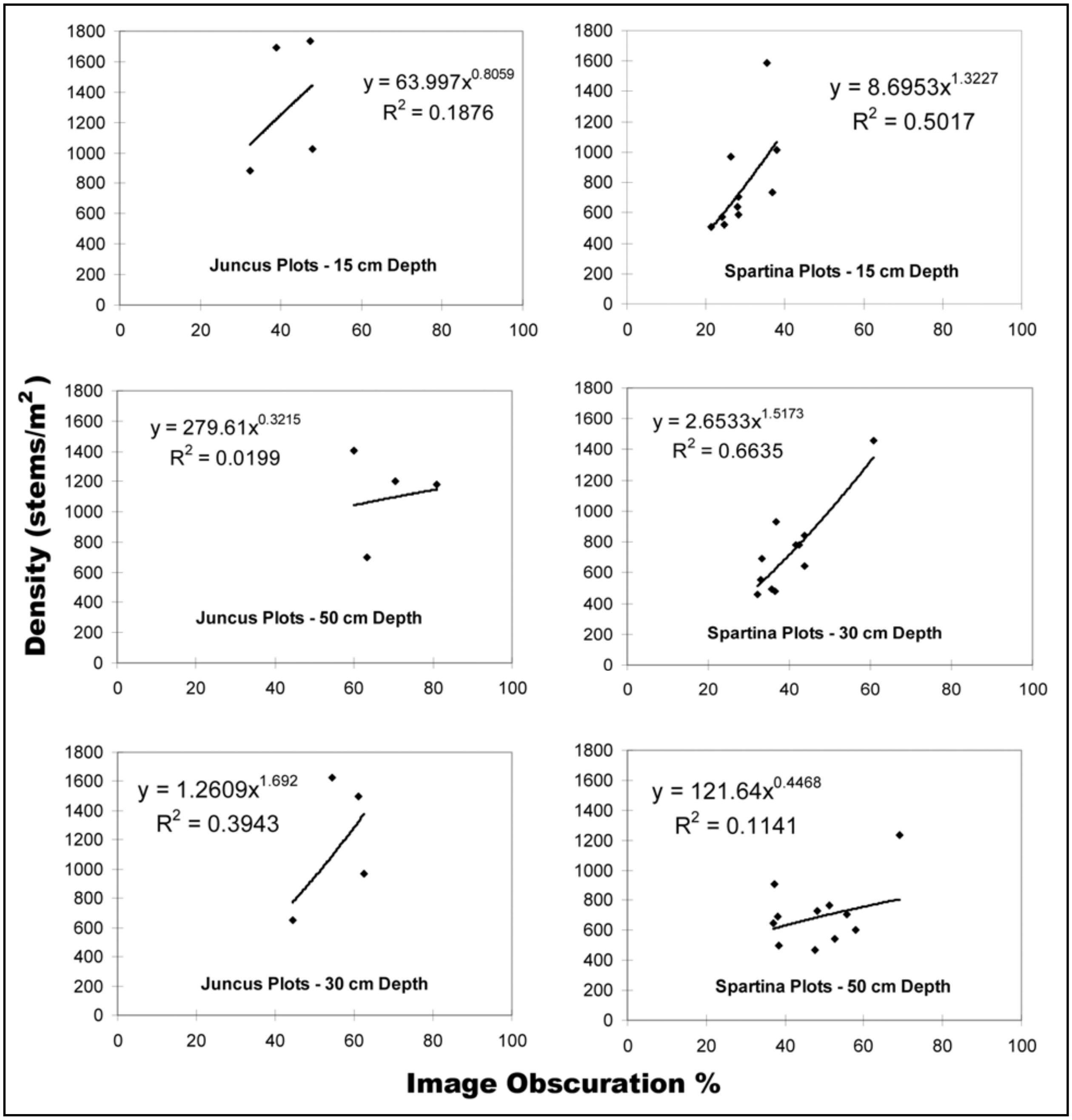

Figure 8. Image obscuration versus stem density in 15-cm depth (0.075 m^2 area), 30-cm (0.15 m^2 area) and 50-cm (0.25 m^2) Juncus and Spartina plots.

Table 3. Comparison of obscuration percentages calculated at different vegetation height segments for three photos using the Feature Analyst (FA) and IMAGINE (IA) methods.

Photo	Obscuration, 0-50 cm		Diff.	Obscuration, 50-100 cm		Diff.
	FA method	IA method		FA method	IA method	
1	39.22%	38.75%	**0.47%**	16.01%	9.60%	**6.41%**
2	56.83%	46.32%	**10.51%**	31.69%	24.75%	**6.95%**
3	63.30%	72.19%	**-8.89%**	32.88%	35.40%	**-2.52%**
Photo	Obscuration, 100-150 cm		Diff.	Obscuration, 0-150 cm		Diff.
	FA method	IA method		FA method	IA method	
1	0.15%	0.08%	**0.07%**	18.16%	18.30%	**-0.15%**
2	7.45%	8.92%	**-1.47%**	30.68%	25.37%	**5.31%**
3	4.77%	5.25%	**-0.48%**	34.71%	40.03%	**-5.32%**

DISCUSSION:

Field Method Issues. Uncontrollable and shifting environmental conditions during field data collection posed many problems in applying the described methodology, resulting in some degree of inconsistency in the quality of the photographs taken. Inconsistent photo quality can, in turn, affect the results of the image analysis. The three major environmental factors that affected the photographs were sunlight, wind, and water depths.

Depending on the direction the backboard is facing, sunlight can be a problem by either creating too many shadows on the backboard, or alternatively, creating too much reflective glare. Generally, glare poses more of a problem than shadows, since shadows can be managed to some extent in the image analysis. However, glare can obscure vegetation and make the photo unusable for analysis (Figure 9). Another confounding factor in the field is the wind, which poses a problem for taller vegetation. Ideally, the wind direction would be directly towards the front of the board. Wind blowing from the side has the effect of swaying a portion of the vegetation so that the backboard is no longer behind it (Figure 10), meaning that the vegetation is not included in the obscuration ratio. In this study, the first priority was to place the board in a direction that would minimize glare, with wind being a secondary concern.

The final environmental problem was that the shifting tide resulted in different water depths (0 to 27 cm) throughout the day. As mentioned in the image analysis methodology section, the obscuration ratio of the underwater vegetation is assumed to be identical to the obscuration ratio in the above-water vegetation up to 50 cm high. Therefore, the higher the water depth, the more potential there is for inaccuracies in the results of the photographic analysis.

Image Analysis Issues. One of the problems with using the 30-cm and 50-cm vegetation depth photographs is that due to a three-dimensional image being translated into a two-dimensional medium, a certain portion of the bottom part of the vegetation is not included in the image analysis (Figure 11). Also, the amount of vegetation that gets cropped will vary based on the distance of the camera away from the board and the focal length of the lens, which means that these factors need to be kept consistent when comparing results from different images. Because of cropping, the calculation does not give a “true” obscuration percentage since much of the vegetation is not included in the calculation. Due to these issues, it is recommended that only 15-cm-depth plots be used in future studies.

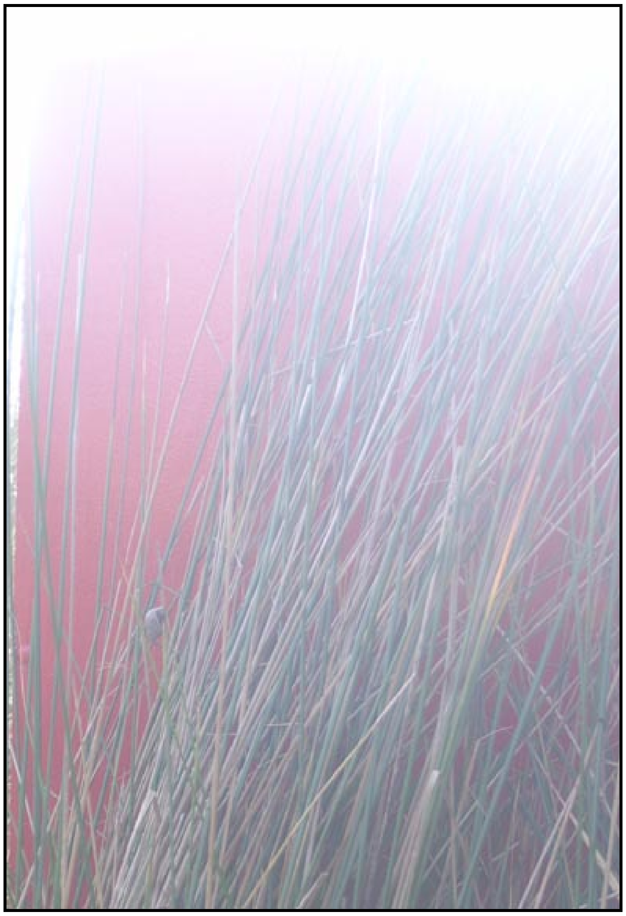

Figure 9. Example of problem posed by glare from sun in photograph.

Figure 10. Example of wind creating a problem with keeping vegetation against the backboard.

Relating Biomass, Density, and Image Obscuration in *S. alterniflora* and *J. romerianus.* The data generally indicate a good non-linear relationship between biomass and obscuration percentage, particularly in the case of plots dominated by *S. alterniflora*. However, because of issues with data quality (as described in the previous sections) and limited sample sizes, accurate empirical relationships cannot be determined based on this preliminary study. There is a much poorer relationship between density and obscuration percentage in both species. Regardless, any relationship that was found between density and obscuration would have to be specific to a given sized sample area, since unlike biomass, which will increase as the sample area or vegetation depth in the photo increases, density does not necessarily change with the size of the sample area.

Data comparisons between *S. alterniflora* and *J. romerianus* plots support the idea that vegetation types within a coastal marsh need to be differentiated to accurately model their effects on waves. However, the magnitude by which these differences would affect wave attenuation is unknown and requires further study. Vegetation in *J. romerianus* plots tended to be taller than vegetation in *S. alterniflora* plots, which largely explains the significant differences in obscuration ratio between the two species in the 50- to 100-cm and 100- to 150-cm height increments. However, there was no significant difference in obscuration ratio between the two species in the 0- to 50-cm height increment. Therefore, the differing obscuration ratios in the species would largely appear to be a function of the variance in height between the two species, rather than being due to any differences in stem structure. Also, at the lower height increment, the influence of stem structure on the obscuration ratio will generally lessen as the density of the vegetation increases.

Figure 11. Example of how the bottom of vegetation is “cropped out” in the image analysis for the 50-cm vegetation depth. The yellow hatched area is the portion of the photo where obscuration percentage is measured.

These trends indicate that the obscuration ratio could be useful as an additional variable in wave attenuation modeling, perhaps as a surrogate for biomass and in addition to or instead of stem density. Additionally, breaking the obscuration ratio down by height increments could be a reasonable way of incorporating plant height into wave attenuation modeling. Since the total plant obscuration ratio will be relative to the height of the board, it makes sense to report the ratio by height increment, rather than as a single number.

FUTURE DIRECTIONS: This pilot study examined the issues involving collection of photographic vegetative lateral obscuration data in coastal Louisiana marshes, as well as the potential for utilizing these data as a variable in numerical modeling of the effects of vegetation on wave attenuation in the area. Additional and more detailed studies are needed before data and results derived from this method can be effectively used in wave attenuation modeling. Future studies should include detailed, controlled flume experiments with real or artificial vegetation. Flume studies would isolate effects of vegetation-induced attenuation from other hurricane processes (e.g., wind-driven wave generation, wave-current interaction), and provide data for calibrating vegetation parameters within models. Additional field data collection that spans the range of variability in marshes of differing vegetation type, height, and density is also needed to expand data sets and validate models. These data could be used to correlate vegetation type databases to model input parameters. Field methods for better controlling problematic environmental factors that affect the quality of the photograph should also be explored. For instance, fully "boxing in" the vegetation and utilizing an artificial light source may be an appropriate way of controlling some of the environmental variability that was discussed earlier in this technical note. Other relevant needs are the development of additional physical parameters characterizing vegetation flexibility/stiffness, relating biomass with obscuration under controlled conditions, and determining under what forcing the vegetation lays down or is uprooted.

POINT OF CONTACT: For additional information contact Sally L. Yost, email: *Sally.L.Yost@usace.army.mil*.

ACKNOWLEDGEMENTS: This project was funded by the Louisiana Coastal Area Science & Technology Program, a partnership between the U.S. Army Corps of Engineers and the Louisiana Office of Coastal Protection and Restoration.

REFERENCES:

Augustin, L. N., J. L. Irish, and P. Lynett. 2009. Laboratory and numerical studies of wave damping by emergent and near-emergent wetland vegetation. In preparation, *Coastal Engineering*.

Cooper, N. J. 2005. Wave dissipation across intertidal surfaces in the Wash tidal inlet, eastern England. *Journal of Coastal Research* 21:28-40.

ERDAS, Inc. 2009. *IMAGINE Version 9.3.* Norcross, GA.

ESRI. 2009. *ArcGIS Version 9.3.* Redlands, CA.

Fonseca, M. S., and J. A. Cahalan. 1992. A preliminary evaluation of wave attenuation in four species of seagrass. *Estuarine, Coastal and Shelf Science* 35:565-576.

Knutson, P. L., R. A. Brochu, W. N. Seelig, and M. Inskeep. 1982. Wave damping in *Spartina alterniflora* marshes. *Wetlands* 2:87-104.

Koch, E., L. P. Sanford, S. N. Chen, D. J. Shafer, and J. M. Smith. 2006. *Waves in seagrass systems: Review and technical recommendations*. ERDC TR-06-15. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Lovas, S. M., and A. Torum. 2000. Effect of submerged vegetation upon wave damping and run-up on beaches. In *Proceedings, 2000 Coastal Engineering Conf.,* 851-864.

Möller, I. 2006. Quantifying saltmarsh vegetation and its effect on wave height dissipation: Results from a UK East coast saltmarsh. *Estuarine, Coastal and Shelf Science* 69:337-351.

Möller, I., and T. Spencer. 2002. Wave dissipation over micro-tidal saltmarshes: Effects of marsh edge typology and vegetation change. *Journal of Coastal Research*, Special Issue 36:506-521.

Möller, I., T. Spencer, J. R. French, D. J. Leggett, and M. Dixon. 1999. Wave transformation over salt-marshes: A field and numerical modeling study from North Norfolk, England. *Estuarine, Coastal and Shelf Science* 49:411-426.

Neumeier, U. 2005. Quantification of vertical density variations of salt-marsh vegetation. *Estuarine, Coastal and Shelf Science* 63:489-496.

Visual Learning Systems, Inc. 2009. *Feature Analyst*. Missoula, MT.

Wallace, S., and R. Cox. 2000. Effects of seagrass on nearshore current and wave dynamics. In *Proceedings, 2000 Coastal Engineering Conference*, 878-890.